# THE INTEGRITY OF WATER

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U.S. Environmental Protection Agency
Office of Water and
Hazardous Materials

# THE INTEGRITY OF WATER

*a symposium*

SYMPOSIUM COORDINATORS:
R. Kent Ballentine and Leonard J. Guarraia
Water Quality Criteria Staff, EPA
Washington, D.C.

## OPENING SESSION

Chairman: Kenneth M. Mackenthun, Acting Director, Technical Standards Division, Office of Water and Hazardous Materials, EPA, Washington, D.C.

Speakers: Kenneth M. Mackenthun

James L. Agee, Assistant Administrator, Office of Water and Hazardous Materials, EPA, Washington, D.C.

Thomas Jorling, Director, Center for Environmental Studies, Williamstown, Massachusetts

Donald Squires, Director, State University of New York Sea Grant Program, Albany, New York

## CHEMICAL INTEGRITY

Chairman: Dwight G. Ballinger, National Environmental Research Center, EPA, Cincinnati, Ohio

Speakers: Bostwick Ketchum, Director, Woods Hole Oceanographic Institute, Woods Hole, Massachusetts

Arnold Greenberg, Chief, Chemical and Radiological Laboratories, State of California Department of Public Health, Berkeley, California

Jay Lehr, Executive Secretary, National Water Well Association, Columbus, Ohio

## PHYSICAL INTEGRITY

Chairman: Richard K. Ballentine, Water Quality Criteria Staff, EPA, Washington, D.C.

Speakers: Donald J. O'Connor, Professor of Environmental Engineering, Manhattan College, New York, New York

Donald R. F. Harleman, Professor of Civil Engineering and Director, Parson's Laboratory for Water Resources, Massachusetts Institute of Technology, Cambridge, Massachusetts

John M. Wilkinson, A. D. Little, Inc., Cambridge, Massachusetts

## BIOLOGICAL INTEGRITY— A QUALITATIVE APPRAISAL

Chairman: Leonard J. Guarraia, Water Quality Criteria Staff, EPA, Washington, D.C.

Speakers: David G. Frey, Indiana University, Bloomington, Indiana

George Woodwell, Brookhaven National Laboratories, Upton, Long Island, New York

Charles Coutant, Oak Ridge National Laboratory, Oak Ridge, Tennessee

Ruth Patrick, Chief, Curator of Limnology, Academy of Natural Sciences, Philadelphia, Pennsylvania

## BIOLOGICAL INTEGRITY— A QUANTITATIVE DETERMINATION

Chairman: David G. Frey, Indiana University, Bloomington, Indiana

Speakers: Ray Johnson, National Science Foundation, Washington, D.C.

John Cairns, Virginia Polytechnic Institute and State University, Blacksburg, Virginia

Gerald T. Orlob, Resource Management Associates, Lafayette, California

J. P. H. Batteke, Chief, Social Sciences Division, Environment Canada, Burlington, Ontario

## INTEGRITY—AN INTERPRETATION

Chairman: Martha Sager, Effluent Standards and Water Quality Information Advisory Committee, EPA, Washington, D.C.

Ronald B. Robie, Director, Department of Water Resources, The Resources Agency, Sacramento, California

Ronald B. Outen, National Resources Defense Council, Washington, D.C.

R. M. Billings, Director of Environmental Control, Kimberly-Clark, Neenah, Wisconsin

Gladwin Hill, National Environmental Correspondent, New York Times, New York

*Following each presentation, Symposium participants were encouraged to question the speaker. These discussions were recorded by a professional reporting service and appear at the conclusion of each paper. They have been minimally edited, simply for clarification of the spoken word in print.*

# FOREWORD

"The Integrity of Water" results from the formal papers and comments presented at an invitational symposium by recognized water experts representing a variety of disciplines and societal interests. The focus of the symposium was on the definition and interpretation of water quality integrity as viewed and discussed by representatives of State governments, industry, academia, conservation and environmental groups, and others of the general public. The symposium was structured to address quantitative and qualitative characteristics of the physical, chemical, and biological properties of surface and ground waters.

It is recognized that streams, lakes, estuaries, and coastal marine waters vary in size and configuration, geologic features, and flow characteristics, and are influenced by climate and meteorological events, and the type and extent of human impact. The natural integrity of such waters may be determined partially by consulting historical records of water quality and species composition where available, by conducting ecological investigations of the area or of a comparable ecosystem, and through modeling studies that provide an estimation of the natural ecosystem based upon information available. Appropriate water quality criteria present quality goals that will provide for the protection of aquatic and associated wildlife, man and other users of water, and consumers of the aquatic life.

This volume adds another dimension to our recorded knowledge on water quality. It brings into sharp focus one of the basic issues associated with the protection and management of this Nation's valued aquatic resource. It highlights, once again, our unqualified dependence upon controlling water pollution if we are to continue to have a viable and complex society. The Congress has provided us with strong and comprehensive water pollution control laws. In accordance with the advances in research and development and with our increased knowledge about the environment, these laws will receive further congressional consideration and modification as appropriate. It is through the efforts of those who participated in making this volume possible that attention is focused once again on the basic goals of water quality to support the dynamic needs of this generation and of others to come.

Douglas M. Costle, Administrator
U.S. Environmental Protection Agency
June, 1977

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# BIOLOGICAL INTEGRITY—1975

G. M. WOODWELL
Biology Department
Brookhaven National Laboratory
Upton, New York

*Sic utere tuo ut alienum non laedas.* Use your own property in such a way that you do not damage another's.

A simple precept, well established in English law, cited by William Blackstone as the basis of the law of nuisance and, I would venture, embraced by most of you and other thoughtful, reasonable men around the world. The principle has many applications. It was advanced recently by Charles Cheney Humpstone in an article in the January 1972 issue of Foreign Affairs in which he argued for an international no-release policy on pollution as the only policy that will work. The precept has its roots, of course, in the biblical morality of doing unto others as one would have them do unto him. Such a code has appealed to reasonable men for more than 2,000 years and has become incorporated into mores, manners, and our laws and interpretations of equity before the courts. As the density of people increases and the potential for intrusions on the interests of others soars, the need for strengthening the morality grows as well—or we degenerate into barbarism—and environment slides rapidly toward a chaos of progressive toxification and impoverishment.

But where lies reason today? The arguments run that reason in the management of environment lies in compromise—between the venal interests of would-be polluters and the so-called "unreasonable" idealism of that class of citizens commonly identified as "environmentalists." And so we find the Administration acquiescing in pressures to delay or annul provisions of the Clean Air Act and we watch continued pressures to weaken the Water Pollution Control Act Amendments of 1972, pressures to dissect and thereby confuse the simple objectives of the Act: to restore and maintain the chemical, physical, and biological integrity of the Nation's waters. The arguments run that the objective is "unrealistic" and "unreasonable." We cannot, they say, live on earth without violation of the objective. That, perhaps, is true if we take a slavishly narrow and prejudicial interpretation of the phrase; but neither can we live in progressive comfort and wealth if we allow accumulating worldwide intrusions on the physical, chemical, and biological integrity of the earth.

And so we are asked now to dissect and define a phrase that should not be dissected. Our interest is in the preservation of the biota including man. The biota is dependent on the physics and chemistry of environment and affects both. In this case all is one and one is all. A dissection is inappropriate.

There is, unfortunately, no universal agreement that the preservation of the biota is in the interests of man. The oil companies can and will buy the fisheries in a time of growing hunger and assert that the world is improved. And if biotic resources are important, they say, which ones? I cannot repair in 5 minutes the accumulated effects of a half century of educational perversion in science. I can but assert that the essential qualities of air, water, and land that make the earth habitable for man are maintained by natural ecosystems in a late stage of evolutionary and successional development. We are now watching regional and worldwide changes in these systems, caused by man, that threaten all. The 1972 Amendments are an acknowledgement of that fact and a step toward recognition in law that the biota provides a series of essential services in addition to food and fiber. The question comes back now: how can we best interpret and strengthen this important law? What new in science can we bring to bear on EPA's job of supporting the law?

The answer is that science can help powerfully, if it will. It will not help powerfully if it acquiesces in the popular belief that compromise among competing exploiters is a sufficient basis for management of the Nation's waters; that all waters have an assimilative capacity for all wastes and management is a simple matter of dividing this assimilative capacity among the users. It will help if it starts with basic principles of science and builds enduring management plans on them. The two most basic principles are evolution and succession. I shall emphasize the latter.

The generalized effect of human activities is to shift both terrestrial and aquatic systems from successionally mature stages to less mature, successional, or "managed" stages. We ask what happens to water when such shifts occur. We recognize that the qualities of lakes and streams are closely coupled to the qualities of their drainage basins and that the "integrity" of a river's functions reaches far beyond the water to the land it drains. How does this water change as the land changes? There is no simple answer; we can, however, examine the concentrations of major nutrient ions in waters draining ecosystems that have been disturbed, such as has been done at Hubbard Brook and elsewhere. Even better we can examine the flux of nutrients along a sere, one unit succession from agriculture to forest within the Eastern Deciduous Forest. The sere I shall use as an example is that leading to oak-pine forest in central Long Island. In this instance, Dr. Ballard and I have measured the quantity of nutrient ions entering the ground water under the various communities of the sere. This ground water flows. On Long Island it flows about 6 inches per day and goes ultimately into ponds, streams, and estuaries along the shore. It is, in addition, a major source of potable water. It is kept flowing by an annual percolation of about 55 cm. How do these plant communities change the qualities of the precipitation as it passes through them to become part of the ground and surface water system?

The flux of anions and cations through these systems is shown in Figure 1. Two trends are conspicuous: first, for most of the ecosystems the effect is to increase the flux of most ions over that in precipitation, despite the high ionic content of New York rain. The ecosystems are net sources of most ions.

Second, the fluxes out of these systems are substantially higher in the younger, least mature successional systems; they are least in the later, forest stages. The difference is especially conspicuous for the nitrate ion where the difference between agriculture and oak-pine forest was more than 1,000 fold, but it applies to virtually all ions except $PO_4$, which moves little under such circumstances.

The sources of the additional ions include fertilizers applied in agriculture and the erosion of primary minerals. The accumulation of nutrients in the net ecosystem production of the rapidly developing successional systems is not sufficient to absorb the nutrients available—and they are lost, to contribute to the eutrophication of water bodies.

If we ask what the ionic flux into the ground water and therefore into streams was prior to the shift into agricultural and successional ecosystems, we find it under the present forest ecosystems. The quality of the water under these communities gives us the best approximation of the nutrient ion content of "normal" water entering lakes and streams in this region. This is the quality of water required

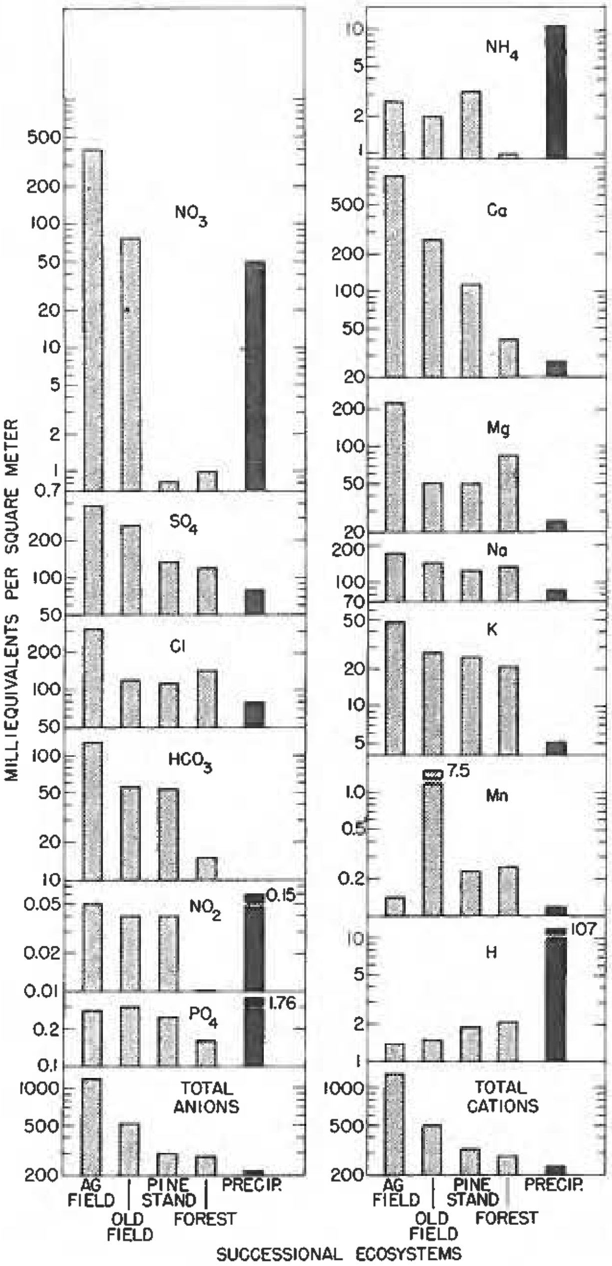


FIGURE 1

to support the mature, evolutionarily-derived aquatic ecosystems of the area. These are the longest lived, least fluctuating, most predictable. While they may not be the most productive of organic matter, they offer a wide range of resources to man, not the least of which is water of high and predictable quality.

Economists and other practical men bridle at the suggestion that management of environment should favor evolutionary and successional maturity. What about cities, agriculture, clear-cut forests, and human wastes—not to speak of toxins such as DDT?

The answer is simple enough; this is the cost of intensive use of environment. We have already moved far toward recognizing the need; we have acknowledged that certain toxins such as DDT, aldrin and dieldrin are intrinsically uncontrollable and cannot be used. In effect we have said that there are aspects of technology that we must forego to live safely together. It is a small further step to accept that industrial wastes are not appropriately made a public responsibility for disposal; they are a part of the cost of industry and to be contained within it.

Similarly, we are faced with the challenge, still poorly recognized, of building closed urban and agricultural systems that mimic in their exchanges with the rest of environment the mature natural systems they displaced. Here is the current challenge for science and government—not to aid in the diffusion of human influences around an already too small world, but to speed the evolution of closed, man-dominated systems that offer the potential for a long, stable, and rewarding life for man.

Unreasonable? Hopelessly idealistic? Perhaps, but only if we reject at this late stage the age-old, time tested precept of other reasonable men: *Sic utere tuo ut alienum non laedas.*

## REFERENCES

Woodwell, G.M., and J. Ballard. Evolution and succession in terrestrial ecosystems: nutrient fluxes in the agriculture-to-forest sere of the Eastern Deciduous Forest. Science (submitted.)

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## DISCUSSION

**Comment:** I wonder, Mr. Woodwell, if you could comment on some ideas on closed urban and agricultural systems? I wonder if you have any further ideas on it?

**Dr. Woodwell:** Do you mean how do we close them?

**Comment:** Yes, and what the elements might look like.

**Dr. Woodwell:** Well, we start with sewage systems. At the moment, many cities are building sewage outfall pipes that will dump sewage, fresh water, and other wastes into the coastal oceans.

That procedure seems to me to be totally inconsistent with the generalized objective stated by the law we're here to discuss. There is a very serious and important challenge to science and government to figure out how to recover the fresh water in sewage and use it again; to recover the nutrients and other wastes; to avoid the inevitable pollution of the coastal waters if those wastes are dumped there; and, to improve the patterns of use of fresh water and nutrients. Another enormous challenge is to figure out how to avoid dumping toxins such as oxides of sulphur and nitrogen into the atmosphere to acidify rains hundreds of miles from the source.

There always are the costs of increasing population and increasing intensity of land use. The alternative to progressive degradation of the environment is to close up our systems. If we are willing to reduce the earth's population to the point where we can live with the open systems that we've had, we can rely on dilution and the well-established concept of assimilative capacity to restore the stability of the resources that we're using.

**Comment:** Would you describe the Brookhaven experiment in closing that loop, both from the kinds of problems you encountered and convincing people it would be a good idea, plus some of the technical problems that you ran into regarding the use of the land?

**Dr. Woodwell:** I suppose that one has to do as one says. Over the past several years, we've built at Brookhaven a series of experiments designed to explore the possibility of closing that sewage loop with the hope that we will make it unnecessary to have offshore disposal of Long Island's waste.

The approach that we used was to start with what we thought we knew. We thought we were experts in water and nutrient cycling in terrestrial and aquatic systems. So we approached the question as to whether we could build a combination of natural and manmade ecosystems for recovering water and nutrients in sewage from the Brookhaven Laboratory sewage treatment plant.

Unfortunately, Brookhaven National Laboratory is a scientific community and it doesn't have very dirty sewage, so we had to get dirtier sewage trucked in. We made special blends of sewage, one the equivalent of the effluent from a primary treatment plant, the other the equivalent of the effluent from a secondary plant.

The plant communities used were the sere from agriculture through to a late-successional forest. We've also used a series of marshes and ponds and meadows to examine the potential of these systems as well, for recovering water and sewage.

To put the story in a nutshell, it is still incomplete, of course, but we now are beginning to remember things. We know that from the standpoint of versatility, certainly agriculture is the best way to absorb nutrients and manage the ground water in terrestrial communities, but other natural communities have a certain definable potential.

The most promising communities are the aquatic ones, the meadows, and the marsh and pond complex. It looks as though we can use a combination of marsh and pond. We built a marsh, most successfully; we built a pond lined with plastic to separate it from the ground water, and the edges of this pond are large plastic pans that support manmade marshes.

It looks as though sewage trickled into these marshes, then into the pond and recirculated. It is really cleaned up very rapidly. This is quite a promising technique.

The point I make is not that there is a single answer to the set of questions I have set forth, but that there are several answers. The answers are likely to be complicated. These that I have outlined here seem to offer one set of possibilities that, by and large, aren't being explored in detail or with great intensity.

We have had no support, for instance, from EPA for this bit of research, although it's a fairly large project, amounting to several hundred thousand dollars a year. It has been financed, interestingly enough, by the old Atomic Energy Commission and by the local government; the town of Brookhaven, Long Island, which has a quite remarkably progressive Republican administration, and has had the foresight to invest very heavily in this kind of research and is learning a great deal from it. I believe they feel rewarded.

I believe that there is in this sort of approach to the sewage problem and to the problem of closing the loop, a need for very great efforts in environmental science, which really changes the direction, the entire objective in the management of the environment.

That is what this law that we're discussing asks us to do. It makes the assumption that we can live on earth only if we preserve the essential integrity of the physical and chemical and biological functions of the environment. That if we continue to allow human influences to diffuse further and further around the world, and with greater intensity, we will destroy those essential functions, and make the world less habitable for man.

So I see here a challenge that just plain isn't being met, by and large, by current research. Current research on energy in big national laboratories such as the one I work at, are focusing on what have been the objectives of science for the past decade, to relieve the expansion of present patterns of industrial and economic activity—further diffusion of human influences rather than the consolidation of those influences into fairly tightly built systems.

**Comment:** In your artificial system, I should say your natural system for removing these nutrients, picking them up in another marsh plant is not closing the loop, is it? Do you have a plan for getting those bull rushes back into cows?

**Dr. Woodwell:** Ideally, of course, one would put them back into agriculture and recirculate them through civilization, but that's hard to do with sewage because we have certain problems with parasites and toxins of various types.

What one can do, however, is to concentrate those nutrients in a place where they can be harvested and reused. They can be used ultimately as fertilizer in agriculture; humus can be moved to agriculture; if there are heavy metals, as there may be in some types of sewage these days, the heavy metals tend to be deposited in the marsh sediments. Then after a time, those sediments can be harvested and treated in whatever way one wants. That seems to me to be a lot better approach than we're using at the moment, allowing them to be dispersed into coastal oceans.

**Chairman Guarraia:** Isn't it a fact that this approach has been taken at Woods Hole with some of Dr. John Ryther's work with agricultural utilization of sewage?

**Dr. Woodwell:** Yes indeed. He has a very elaborate, large project in which they're exploring the possibilities of using marine organisms, plants, filter feeders, and marine animals, to scrub the nutrients out of sewage.

It has the disadvantage, of course, of still resulting in the loss of the fresh water; the fresh water is mixed with saltwater, and then lost. It has the advantage that the water that's released is low in nutrients. They can do all this with a very high degree of efficiency.

Perhaps Dr. Ketchum would like to comment on that.

**Dr. Ketchum:** I think you've stated it properly and adequately. I think it's worth mentioning the Penn State studies in which they have fertilized agricultural crops. It's not uncommon in the West in irrigation processes.

**Dr. Woodwell:** Yes. I haven't mentioned a thousand other projects that have been carried out over the past decades—some of them have gone back even centuries—in which sewage has been used in parallel approaches.

I think that we have the advantage at the moment of having learned a lot about the structure of ecosystems and the circulation of nutrients. It's useful to put this theory and detailed knowledge into practice.

**Comment:** The thing that we're hearing now with regard to returning the sewage to its natural system is the possibility of not only returning it to its natural system, but contaminating our source of ground water, which is underneath that natural system and never was exposed to these pollutants in the first place. Especially, some of the concern raised about the problem of chemicals in the surface water. People are inclined to turn more and more to the ground water for their drinking source.

Is there any way, at least in a temporary sense, that you can get the waste back on the land without getting the ground water contaminated as well?

**Dr. Woodwell:** I think so. I think the most common problem, at least in my experience in Long Island, is with nitrogen-nitrate, in particular.

There are various ways of removing nitrogen. The meadows that we're working with are very, very efficient at removing nitrogen, removing well over 95 percent of it; so do the ponds and marshes.

So if first treatment involves trickling through a meadow or passage through a marsh and pond, we wind up with very low concentrations of total nitrogen.

The heavy metals that concern many of you, I suspect, tend to be sedimented in the marsh and in the meadow, as well. So they are localized and not transported.

**Comment:** Have you been able to trace any of the more exotic viruses that have shown up? For example, in the EDS studies?

**Dr. Woodwell:** No. That's one of the failures of my program at the moment. It just hasn't been done.

**Comment:** It's not that it can't be done; it just hasn't been done yet.

**Dr. O'Connor:** I'm sure that most of us with reasonable intellect subscribe and agree with the principles you've enunciated. I guess our problems arise, not so much in acceptance of those basic moral issues, as in answering specific problems while we have such short time here for ourselves and our future.

In this sense, I guess I have to disagree with some of the things you said, or maybe add to them. Let me first try to add something and then disagree.

I would add one other aspect to your fine talk; it is incorporating flexibility into our environmental planning. Let's not lock ourselves in too strongly, as with returning things to the Great Lakes. If we mess it up, we're going to mess it up for years.

It's precisely on that basis, getting more directly to our home area, that I disagree so strongly with some of the components that I think you and others have agreed upon; returning the treated effluent of Long Island to the ground water is exactly the last point you raised.

Whereas, if we do return to the ocean for a short time, we have two potential advantages. One is the flexibility—we're not locking ourselves into potentially destroying a water resource. Secondly, the return of nutrients to land, as you implied, can be equally beneficial to sea. It's an extension of what you said. Therefore, I think one would be a little hard pressed to argue strongly for returning it to ground water.

**Dr. Woodwell:** By the time we have built a, roughly, billion dollar sewage collection system treatment plant and a sewage outfall pipe that costs about $60 million, one hardly thinks of this as an easily reversible, flexible sewage management system.

The investment of $60 million for a sewage outfall pipe is sufficient capital investment that I just don't think that we're going to change that plan in a hurry.

Going beyond that to pursue the flexibility aspect, it is true that we can increase the primary productivity of limited areas in the ocean by adding nitrogen compounds and phosphorus to them. And, it's also true that the coastal oceans have a certain assimilative capacity for organic matter and other human wastes.

But it isn't true that they have an assimilative capacity for all toxins. Most people these days agree that we don't have room in the oceans for persistent chlorinated hydrocarbons such as DDT and PCBs. It's very hard to keep those out of the sewage of New York, for instance.

So, while we might establish the idea of an assimilative capacity for certain substances in sewage, that assimilative capacity doesn't apply, generally, to what comes with that sewage. Is that true?

**Dr. O'Connor:** Quite true. As I suggested this morning, I'm not referring to the principle of assimilative capacity, but the one that you enunciated yourself, that is the residual materials in the treated effluent are good for the land and its natural recycling system. I'm simply submitting that they could be equally good for the water in a natural recycling system.

So, the option is open both ways. I would add one other point. Just as hydrocarbons are bad for the ocean, I would say, considering the groundwater resource and the use we make of it in Long Island, it is doubly bad for the return there.

Finally, just a little rub. I'm glad to see you are conscious of forces.

**Dr. Woodwell:** Very good. I think that the possibilities of handling sewage on land are very great. It's hardly inflexible. We have physical-chemical systems for sewage treatment; we can take out chlorinated hydrocarbons and not put them into the ground water. In fact, it's very hard to get them into the ground water because they tend to be absorbed in places on the surface of the ground.

One of the best, the classic approach to physical-chemical treatment is, of course, with charcoal filters of various types. The humus layer of forest, or the organic sediments of the marsh or a meadow, come very close to being precisely that. They pick up virtually everything.

So, I think of the terrestrial and aquatic, as opposed to marine approaches, as being extremely versatile, and not fantastically expensive.

**Dr. Patrick:** I just wanted to clarify one point which you raise. That is, in order to keep sewage from getting into the ground water, the Campbell Soup Company did a remarkable piece of work in which they put tiled drains under their spray irrigation areas, and these tiles collect the excess that runs down and is not picked up; and that is resprayed or put into a pond, and it is then acted on by algae.

**Dr. Woodwell:** Very good, Ruth, thank you. I think I can guarantee that I can produce a system for absorbing nutrients and toxins on the surface of the ground that will not result in contamination of the ground waters.

I see heads shaking. I can see that we have a lot of research to do.

**Comment:** The concept of land disposal of sewage is not particularly new to this world. I mentioned yesterday the CSEOLM Study of the Chicago District of the Corps of Engineers done about a year ago. CSEOLM was an acronym for Chicago South End of Lake Michigan.

What they were looking at was the sewage and flood water in the entire metropolitan Chicago area. One of the proposals made in this study was land disposal of all of the wastewaters from the metropolitan Chicago area—something very much along the lines that you discussed.

One of the things from which the proposal suffered was that the land that would be required for this wasn't measured in acres, it was measured in counties. It would have required, I can't tell you off the top of my head, how many millions of acres, but as I recall, it was measured in millions.

Do you think it is a wise way of utilizing our land resources to put enormous land areas under this kind of what might be called stress?

**Dr. Woodwell:** To answer that, I suppose we ought to take a quick look at what we do now. What we do now, of course, is to partially treat this waste. If we're in New York City, we then release it into some water body that connects to the New York Bight, losing the fresh water for any new, immediate use; losing a good fraction of the nitrogen and phosphorus, the nutrients; and, without question, polluting the coastal waters.

In addition to that, there are certain hazards connected with dumping this partially treated waste into coastal waters. Coastal waters are indeed degraded by this process over large areas, so there is a cost which we don't calculate at the moment or enter into the calculation of what it takes to run a city.

In addition to that, we generate large quantities of sludge which are, in New York City, hauled out in special barges into the New York Bight and dumped. And you EPA people know that this is an increasing problem.

That's what we do right now. Now the alternative to this, at least what I'm saying is an alternative, is to do research on how we recover the water and nutrients, keeping them on land and restoring the water to a usable condition.

If it takes a large land area, that, unfortunately, is the cost of intensive use of the environment. I see that as the only way in which we can intensify the use of environments otherwise degraded. We lose the coastal fisheries, and almost no one is saying these days that we ought to do that.

**Comment:** Given that there is a large land requirement probably involved with your marshes and meadows, how does this system stack up in terms of their normal ecosystem productivity? In other words, can birds and animals that would characteristically be found in marshes and meadows, survive in these artificial waste treatment systems and would they survive? Do you have any experience on that yet?

**Dr. Woodwell:** It's a little premature, I suppose. The marshes that we have built are attractive to ducks and geese and great blue herons; certainly the ponds support fish. I don't see any reason why these experimentally enriched systems can't be a part of the matrix of natural systems that are the general environment.

**Dr. O'Connor:** There was one other point that you raised that I would like to address.

I understood your prerogative to speak and put in a black and white fashion the conflict between the environmentalist and the industrialist. Certainly one can subscribe to the principle of your point. I think it's unrealistic, as I tried to say this morning, given the fact that we live in a technological, industrial society.

To address the issue, in my mind it's simplistic, that you're going to change the structure of society. Now, I fully agree with much of that, and our standard of living. But it seems to me that the issues are not so much between the environmentalist and the industrialist as with all the other basic needs society has. There's a conflict of those monies to alleviate poverty; there's a whole priority of social needs that have to be put into perspective with the environmental. And I think that is a more critical issue.

**Dr. Woodwell:** You put your finger on the very core of what concerns ecologists, scientists of the environment, at the moment. It's a very large topic, one that isn't easily examined in detail in a moment.

The question comes back as to what are the fundamental resources in support of man? What does it take to keep us on earth? We in the Western world tend to think that it takes a healthy economy, fed by lots of fossil fuel energy, and that nuclear energy is going to displace this, and that the technology that's built on this free flow of fairly inexpensive energy is going to solve all the problems of man. That is simply not so in the eyes of biologists who study environment.

We have heard in great detail about the changes that occur in the rivers with channelization; that as soon as we channelize the river, the normal functions of the river that were performed by biotic systems are taken over by man, at considerable cost. As a result of the channelization, the depth of floods increases. Sediment loads increase and a whole new array of problems appears that requires another tax on the general public to resolve.

That isn't different from other aspects of the environment where we gradually take over management from biotic systems. And we aren't very good at that kind of management. If we were good at it there wouldn't be a problem in channelization, there wouldn't be a problem in management of the coastal oceans or in management of lakes.

**Dr. O'Connor:** I agree we are no good on it. We have very little experience or background, so we will accept the principle of flexibility then.

**Dr. Woodwell:** I'm not sure what I'm accepting. So we come back to what our basic resources are. Our basic resources worldwide are not energy or the economy or anything else. The basic resources are biotic resources. These are the resources that are used by all of the people on earth, all of the time.

Much more energy flows to the support of man through biotic resources then flows through industrial systems. Much more energy, by a factor of 20 or so, at least, worldwide. It's only here in the United States, and for probably a fairly short time, that we live with the enormous wealth that cheap industrial energy has given us.

Although this gives us the opportunity to use other resources, as populations increase and demand on environment grows, we have to use our resources in totally different ways in order to avoid degrading the much more fundamental biotic resources that are essential to all of us.

That's the point the ecologists and scientists have to make, and that should be the point of research. A lot of research, right now while we can do it, on how to close up these systems and live for a long time with a finite set of biotic resources.

Perhaps an infinite technology, but it hasn't changed the basic rules of the game. The basic rule of the game is that everybody eats plants.

**Comment:** I guess it's not a question, but a comment that I'd like you to say you agree with. I have a couple of observations on the story of wastewater disposal in Illinois. I think the program was victimized by a poor job of public relations there, which is typified by the description of the project as the disposal of wastewater. It's not disposal and it's not wastewater. They might have called it the recycling of essential nutrients, and told the counties involved that they had chosen the lucky number and had been chosen to receive a great deal of free irrigation water and fertilizer as a gift from the city of Chicago.

My point is that a great deal of the time a lot of the stigma involved is dependent upon what you call the thing.

Secondly, I don't think that the utilization of land resources for the receipt of these materials precludes its use for all the other things that are already there. In fact, I think it enhances it. So, it isn't like two or three counties have to move somewhere else. In fact, their agricultural space might be increased. I think that's the point of your talk.

The third point is to the gentleman over here. I recall some work we did on a marsh in North Carolina, which by accident was unlucky enough to get at the end of the pipe. It was not any sort of a treatment system, but it was that kind of marsh. It was a great deal more productive, not only in plant biomass, but also in all the other things associated with it. And one was struck by this just walking onto the sight.

If there had been, in fact, a scheme to harvest that material and do something with it rather than let it fall right back into the water and simply pass those nutrients on down, it might have been a very good and efficient way of returning that material.

**Dr. Woodwell:** Very good, I'll agree with all of that.